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**13. ABSTRACT** ***(Maximum 200 Words)***

The Center for Optoelectronics and Optical Communications at the University of North Carolina at Charlotte hosted a workshop on Inverse Scattering from May 30th to June 3rd. Topics discussed included inverse surface reconstruction, inversion of objects in random media and below rough surfaces, inversion of penetrable and partially coated objects and properties of non-scattering scatterers. This was a residential workshop organized along the lines of a Gordon Conference, with talks throughout the day punctuated with ample time for discussion. There were forty four participants from all over the world and twenty seven gave presentations.

In the spirit of a Gordon conference, brief abstracts of the presentations were provided to all of the participants but there was no expectation that authors provide a written paper. However authors were asked if they would like their presentations circulated on a CD which would then be made available to participants and sponsors and also whether they might to consider submitting their work to a special issue of the journal Waves in Random and Complex Media. Many agreed to both and the final report consists of the workshop digest and a CD containing almost all of the presentations.

**14. SUBJECT TERMS**
Scattering, Inverse Scattering, Rough Surfaces, Imaging

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# The Charlotte Research Institute

## and the

## Center for Optoelectronics and Optical Communications

# 2005 CRI Summer Conference on Inverse Scattering

*"for the unique opportunity to interact and share ideas"*

***May 30 - June 3, 2005***
***on the UNC Charlotte Campus***

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***Hosted by:***



UNC CHARLOTTE

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## The 2005 CRI Summer Conference

# Inverse Scattering Workshop

*May 30, 2005*

The Center for Optoelectronics and Optical Communications at the University of North Carolina at Charlotte welcomes participants to its workshop on Inverse Scattering. This is the second summer conference to be sponsored by the Charlotte Research Institute and it is co-sponsored by AFOSR, General Dynamics and Taylor and Francis. We are very grateful to all of our sponsors for their support.

The intention behind this workshop is to bring together experts in the areas of scattering and inverse scattering and to provide a stimulating environment in which ideas can be shared and discussed. Following the style of a Gordon Conference, we hope to have provided sufficient time throughout each day and in the evenings for participants to interact with each other.

Scattering and inverse scattering represent fundamental subjects that impact how we probe and learn more about the world around us. This workshop is primarily for those working on the theory and numerical methods associated with electromagnetic and acoustic scattering problems. The intellectual challenge that brings us together is advancing the underlying theoretical models and algorithms that can transform measured data into needed information. Some specific inversion requirements have proved particularly difficult over the years, such as imaging objects surrounded by clutter and noise. Topics being presented in this workshop include the remote sensing of surfaces, inversion of data scattered from random media, detection and imaging of objects buried below rough surfaces, inversion of penetrable and partially coated targets and the properties of stealth scatterers. Applications of these topics are many and include detecting buried mines, bunkers, objects under foliage, numerous nondestructive testing/nondestructive evaluation problems in inspection and metrology and, in the medical realm, imaging features such as tumors in tissue. A challenge the group will address is that of accurately modeling scattering from objects that are within or on strongly scattering (i.e. cluttered) backgrounds.

In the spirit of a Gordon Conference, we publish here only brief abstracts of the presentations and do not require authors to provide a written paper. However, we are encouraging authors to consider submitting their work to a special issue of the journal *Waves in Random and Complex Media*, published by Taylor and Francis, if they wish.

A special thanks goes to those who have had to deal with all of those inevitable logistical and planning details that go into making a workshop such as this a success. This meeting would not have been possible without the hard work and dedication of Karen Ford, Dodie Hart, and Shirley Joyner. Thanks also to Chris Gilbert and Scott Williams. Finally I would like to thank John DeSanto of the Colorado School of Mines and Michael Klibanov of UNC Charlotte for their help with the technical program.

**Mike Fiddy**
*Director*
*Center for Optoelectronics and*
*Optical Communications*
*The University of North Carolina at Charlotte*
*Charlotte, NC USA*

UNC CHARLOTTE

**James H. Woodward**

**Chancellor**

Since becoming UNC Charlotte's third chancellor in 1989, Dr. James H. Woodward has established himself as one of the leading executives of the Charlotte metropolitan region. A U.S. Air Force veteran, he worked in private industry and taught at N.C. State University, the Air Force Academy and the University of Alabama at Birmingham, where he was senior vice president for academic affairs, prior to coming to UNC Charlotte.

Under his leadership, UNC Charlotte has launched ambitious plans for both physical and intellectual growth, including a Master Plan for expanding campus facilities to accommodate 25,000 students and an Academic Plan to expand master's degree and doctoral programs. Early in his tenure he led the university in doubling its $16 million goal in a campaign that raised $32 million. In 2002, he launched the university's first $100 million campaign, securing a $10 million commitment from the Duke Energy Foundation – the largest investment made by the foundation and with Duke's other commitments, the largest received by the university. He built strong support among the region's corporate and political leadership, obtained approval for expanding the university's mission to include Ph.D. programs and raised the university to doctoral/research intensive status. He also took the lead in establishing UNC Charlotte Uptown as an off-campus center, serving people who live and work in the central business district. An engineer, Woodward generated financial support to build the James H. Barnhardt Student Activity Center and the Irwin Belk Track and Field Center, obtained state funding for doubling the size of Atkins Library and was instrumental in garnering public support to pass a $190 million bond referendum that is enabling UNC Charlotte to construct or renovate nearly a dozen buildings.

He has been active in both the Arts and Science Council of Charlotte and the United Way of the Central Carolinas and led the 1996 United Way Campaign that raised more than $22 million.

In recognition of his leadership, he was presented the 1996 Manager of the Year Award by the Charlotte Chamber of Commerce, Charlotte Rotary and Charlotte Business Journal. He also received a Distinguished Alumnus Award and an honorary degree from the University of Alabama at Birmingham. In 2003 the National Conference for Community Justice presented him with a Humanitarian Award, and that same year he received the Lifetime Achievement Award from Leadership Charlotte. After 16 years at the helm, Woodward will retire on June 30, 2005.

# Special Thanks

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## Inverse Scattering Workshop

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*The University of North Carolina at Charlotte*

*2005 Charlotte Research Institute Summer Conference*

# INVERSE SCATTERING WORKSHOP

*May 30 – June 3, 2005*

## AGENDA

*All activities in Cameron Applied Research Center Room 101 unless otherwise noted*

### Monday, May 30

| | | |
|---|---|---|
| **7:30 AM** | *Breakfast at Prospector Gold Room* | |
| **8:30 AM** | **Chancellor James Woodward**<br>*Welcoming Remarks* | University of North Carolina<br>At Charlotte |
| **8:40 AM** | **Mike Fiddy**<br>*Opening Session* | University of North Carolina<br>At Charlotte |
| **9:00 AM** | ***Waves in Random and Complex Media Lecture:***<br>**Sergey Kabanikhin**<br>*Direct and Iterative Methods of Solving Inverse Electromagnetic and Acoustic Problems* | Sobolev Institute of Mathematics<br>Novosibirsk State University<br>Novosibirsk, Russia |
| **Break** | *Cameron Room 119* | |
| **10:30 AM** | ***Charlotte Research Institute Lecture:***<br>**Akira Ishimaru**<br>*Detection and Imaging of Objects Behind Multiple Scattering Random Obscuring Layers* | University of Washington<br>Seattle, WA |
| **11:30 AM** | **Discussion of topics for workshop breakout sessions** | |
| **Lunch** | *Cameron Room 119* | |
| **2:00 PM** | **Social Event:** Discovery Place/Imax Theater and Downtown Charlotte | |
| **Dinner** | *Downtown at Rock Bottom Restaurant* | |

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# INVERSE SCATTERING WORKSHOP

## AGENDA

*All activities in Cameron Applied Research Center Room 101 unless otherwise noted*

### Tuesday, May 31 - Imaging

| | | |
|---|---|---|
| **7:30 AM** | *Breakfast at Prospector Gold Room* | |
| **8:30 AM** | **Francesco Zirilli**<br>*Inverse Scattering and Smart Obstacles* | Universitá Di Roma La Sapienza<br>Roma, Italy |
| **9:15 AM** | **Greg Gbur**<br>*Nonradiating Sources, Nonscattering Scatterers, and other "Invisible Objects"* | University of North Carolina<br>Charlotte, NC |
| **Break** | *Cameron Room 119* | |
| **10:30 AM** | **Qing Liu**<br>*Inverse Problems for 3D Objects in Layered Media* | Duke University<br>Durham, NC |
| **11:15 AM** | **Gary Brown**<br>*Surface Wave Propagation Over Gently Undulating Rough Surface: a Forward Problem with Inverse Applications* | Virginia Polytechnic Institute<br>& State University<br>Blacksburg, VA |
| **Lunch** | *Cameron Room 119* | |
| **2:00 PM** | **Marc Saillard**<br>*Surface clutter removal in inverse scattering from buried objects* | Université de Sud Toulon-Var<br>La Garde Cedex, France |
| **2:45 PM** | **Lawrence Carin**<br>*Investigation of the Stability of Electromagnetic Time-Reversal Imaging* | Duke University<br>Durham, NC |
| **Break** | | |
| **4:00 PM** | **Anthony J. Devaney**<br>*Time Reversal Imaging and Inverse Scattering* | Northeastern University<br>Boston, MA |
| **Dinner** | *Prospector Gold Room* | |

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# INVERSE SCATTERING WORKSHOP

## AGENDA

*All activities in Cameron Applied Research Center Room 101 unless otherwise noted*

### Wednesday, June 1 - Surfaces

| | | |
|---|---|---|
| **7:30 AM** | *Breakfast at Prospector Gold Room* | |
| **8:30 AM** | **John DeSanto**<br>*Rough Surface Reconstruction* | Colorado School of Mines<br>Golden, CO |
| **9:15 AM** | **Alexei Maradudin**<br>*The Design of Surfaces with Specified Scattering Properties* | University of California<br>Irvine, CA |
| **Break** | *Cameron Room 119* | |
| **10:30 AM** | **Tom Lucas**<br>*A New Inverse Solver for Diffusion Tomography Using Multiple Sources* | University of North Carolina<br>Charlotte, NC |
| **11:15 AM** | **Iosif Fuks**<br>*Statistical Properties of the Ensemble of Specular Points at a Randomly Rough Surface* | NOAA Environmental<br>Technology Laboratories<br>Boulder, CO |
| **Lunch** | *Cameron Room 119* | |
| **2:00 PM** | **Eugenio Mendez**<br>*Inverse Scattering Using Evolutionary Strategies* | CICESE<br>Ensenada, Mexico |
| **2:45 PM** | **Mike Fiddy**<br>*Minimun-phase-based Inverse Scattering Algorithm* | University of North Carolina<br>Charlotte, NC |
| **Break** | *Cameron Room 119* | |
| **4:00 PM** | **Breakout Session** | |
| **Dinner** | *Prospector Gold Room*<br>*Followed by informal discussion/bar* | |

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***2005 Charlotte Research Institute Summer Conference***

# INVERSE SCATTERING WORKSHOP

## AGENDA

*All activities in Cameron Applied Research Center Room 101 unless otherwise noted*

### Thursday, June 2 – Inverse Problems

| | | |
|---|---|---|
| **7:30 AM** | *Breakfast at Prospector Gold Room* | |
| **8:30 AM** | **John Schotland**<br>*Inverse Scattering and Nano-Optics* | University of Pennsylvania<br>Philadelphia, PA |
| **Break** | *Cameron Room 119* | |
| **10:00 AM** | **John Sylvester**<br>*The Scattering Support of a Far Field* | University of Washington<br>Seattle, WA |
| **10:45 AM** | **Markus Testorf**<br>*Retrieval of Phase Information in Phase-Space* | Dartmouth College<br>Hanover, NH |
| **Lunch** | *Cameron Room 119* | |
| **2:00 PM** | **Michael Klibanov**<br>*Some Inverse Problems including the Phase Problem in Optics* | University of North Carolina<br>Charlotte, NC |
| **2:45 PM** | **Paul Carter and Mike Milder**<br>*The Virtual Periscope* | Areté Associates<br>Sherman Oaks, CA |
| **Break** | *Cameron Room 119* | |
| **4:00 PM** | **Irena Lasiecka**<br>*Wellposedness and Uniform Decay Estimates for Nonlinear Schrödinger Equation with Boundary Damping* | University of Virginia<br>Charlottesville, VA |
| **4:30 PM** | **Roberto Triggiani**<br>*Pointwise Carleman Estimates for Schrödinger Equations: Global Uniqueness, Observability and Stabilization* | University of Virginia<br>Charlottesville, VA |
| **5:00 PM** | **Breakout Sessions** | |
| **Dinner** | *Outside Barbecue on Campus* | |

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## *2005 Charlotte Research Institute Summer Conference*

# INVERSE SCATTERING WORKSHOP

## AGENDA

*All activities in Cameron Applied Research Center Room 101 unless otherwise noted*

### Friday, June 3 – Inverse Scattering

| | | |
|---|---|---|
| **7:30 AM** | *Breakfast at Prospector Gold Room* | |
| **8:30 AM** | **Valentin Freilikher**<br>*Inverse Scattering Problem for One-Dimensional Random Systems* | Barilan University<br>Ramat-Gan, Israel |
| **9:15 AM** | **Yuri Godin**<br>*Propagation of waves in a one-dimensional random binary medium* | University of North Carolina<br>Charlotte, NC |
| **Break** | *Cameron Room 119* | |
| **10:30 AM** | **Johannes Elschner**<br>*Inverse Problems for Diffraction Gratings* | Weierstrass Institute for Applied Analysis and Stochastics<br>Berlin, Germany |
| **11:15 AM** | **George Hsiao**<br>*On an Inverse Scattering Problem for Periodic Structures* | University of Delaware<br>Newark, DE |
| **Lunch** | *Cameron Room 119* | |
| **2:00 PM** | **Andrew Hesford**<br>*Reducing the Asymptotic Complexity of the Distorted-Born Iterative Method* | University of Illinois<br>Urbana-Champaign, IL |
| **Break** | *Cameron Room 119* | |
| | **Wrap-up Discussion Session** | |

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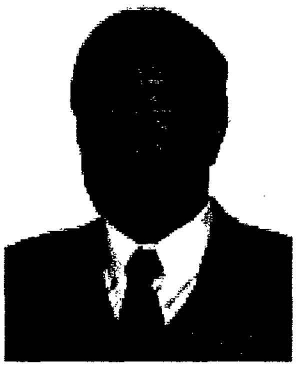
*Please accept our apologies for any incorrect renderings of mathematical formulas*



# Sergey Igorevich Kabanikhin

**Sobolev Institute of Mathematics,**
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## WRCM Lecture

SERGEY KABANIKHIN was born in 1952 in Batagai, Yakutia, Russia. He received the B.E. in Mathematics (1974) and M.S. in Mathematics and Applied Mathematics (1975) from the Department of Mathematics and Mechanics, Novosibirsk State University, Russia, followed by Ph.D.,Differential and integral equations (Advisor Professor V.G. Romanovi) in 1978 and Doctor of Sciences, Computational Mathematics in 1990, from Novosibirsk, Computer Center of Siberian Branch of Russian Academy of Sciences, Novosibirsk (Russia). From 1975-1984 he was Research Scientist and from 1984-1987 Senior Research Scientist at the Computer Center, Novosibirsk. He then moved to the Institute of Mathematics, Novosibirsk, where he was a Senior Research Scientist from 1987-1990. In 1990 he assumed his current position as Chief Research Scientist and a full Professor at Novosibirsk State University. He has held visiting positions at Geophysical Institute of Prague; Mathematical Institute of Bulgarian Academy of Science, Sofia, Bulgaria; Kazakh Branch of All Union Institute of Prospecting Geophysics; All Union Institute of Geophysics and Well-Logging, Tver; Royal Institute of Technology, Stockholm; Milan University, Florence University, and Perugia University, Italy; Kyoto University and University of Tokyo, Japan; Cambridge University, UK; University of Karlsruhe, Germany; University of Hanzhou, China; and University of Innsbruck, Austria. His research interests include Electrodynamics, Acoustics, Elasticity; Partial Differential Equations; Hyperbolic Equations and Wave Phenomena; Inverse and Ill-Posed Problems; and Mathematical and Computational Modeling. Dr. Kabanikhin is the author of seven books and numerous journal articles.

**ABSTRACT: Direct and Iterative Methods of Solving Inverse Electromagnetic and Acoustic Problems**

The problem of determining coefficients of Maxwell's and acoustic equations using additional information about their solutions are of a great practical significance. The desired coefficients are important characteristics of the medium such as as dielectric permeability and magnetic permittivity, conductivity, the density and the velocity of wave propagation. We consider the dynamical type of inverse problem in which the additional information is given by the trace of the direct problem solution on a (usually time-like) surface of the domain. This kind of inverse problem was originally formulated and investigated by M.M. Lavrent'ev and V.G. Romanov (1966). In this talk we will discuss the theoretical and numerical background of iterative and direct methods. We will formulate and prove theorems of convergence, conditional stability and other properties and will discuss the results of numerical experiments.

Research devoted to the study of dynamic inverse problems deal with one of the following basic methods: the method of Volterra operator equations, Newton-Kantorovich method; Landweber iteration and optimization; the Gel'fand-Levitan-Krein and boundary control methods, the method of finite-difference scheme inversion and linearization. The first group of methods, namely, Volterra operator equations, Newton-Kantorovich, Landweber iteration and optimization produce the iterative algorithms where one should solve the corresponding direct (forward) problem and adjoint (or linear inverse) problem at every step of the iterative process. Conversely, the Gel'fand-Levitan-Krein method, the method of boundary control, the finite-difference scheme inversion and sometimes linearization methods allow one to find the solution in a specific point of the medium and we refer to them as the "direct" methods. We will discuss theoretical and numerical backgrounds of iterative and direct methods and will formulate and prove relevant theorems and discuss numerical experiments.

**Akira Ishimaru**

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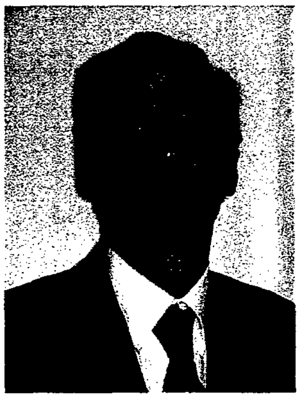
## Charlotte Research Institute Lecture

**Akira Ishimaru** joined the faculty of the Department of Electrical Engineering of the University of Washington, where he was a Professor of electrical engineering and an Adjunct Professor of applied mathematics. He is currently Professor Emeritus there. His current research includes waves in random media, remote sensing, object detection and imaging in clutter environment, inverse problems, millimeter wave and optical propagation and scattering in the atmosphere and the terrain, rough surface scattering, optical diffusion in tissues, and metamaterials. He is the author of *Wave Propagation and Scattering in Random Media* (Academic, 1978; IEEE-Oxford University Press Classic reissue, 1997) and *Electromagnetic Wave Propagation, Radiation, and Scattering* (Prentice-Hall, 1991). He was Editor of *Radio Science* and Founding Editor of *Waves in Random Media*, Institute of Physics, U.K. He is a Fellow of the IEEE, OSA, ASA, and IOP. He was the recipient of the IEEE Region VI Achievement Award and the IEEE Centennial Medal. He was appointed as Boeing Martin Professor in the College of Engineering. He was awarded the Distinguished Achievement Award from the IEEE Antennas and Propagation Society. He was elected to the National Academy of Engineering. He was awarded the Distinguished Achievement Award from the IEEE Geoscience and Remote Sensing Society. He is the recipient of the IEEE Heinrich Hertz Medal and the URSI Dellinger Gold Medal. He received the IEEE Third Millennium Medal.

### ABSTRACT: Detection and Imaging of Objects Behind Multiple Scattering Random Obscuring Layers

This paper presents a theory of imaging objects behind layers of scattering media. The transmitter is a focused array or aperture emitting a short pulse. The pulse is multiply-scattered by the random obscuring layer, reaches the object and is scattered back through random layers. The scattered pulse wave is received by a focused array or aperture. The received signal consists of the scattered wave from the layer as well as the object. While the cw scattered wave cannot be distinguished between these two components, UWB can detect the object through the obscuring layer. The theory requires the development of a generalized two-frequency mutual coherence function based on the parabolic approximation. This is based on the second-order phase perturbation and is flexible. It conserves the power and can include any medium spectrum. When the medium spectrum is Gaussian, it reduces to the known solution. This imaging theory is similar to optical coherence tomography (OCT) and a generalization of SAR and confocal imaging. It also makes use of the complex circular Gaussian assumption to reduce the fourth-order moments to the second-order moments. It clarifies the relationships among resolution, coherence length, shower curtain effects, and backscattering enhancement.



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FRANCESCO ZIRILLI was born in Genova August 12,1949. He received the Laurea in Mathematics 1971, Laurea in Physics 1972, and held a graduate fellowship at Scuola Normale Superiore Pisa. He was a research fellow Courant Institute New York University, Rockefeller University, Harvard University, contrattista MPI Universita' Roma La Sapienza. Other positions include adjunct professor Universita' Camerino, visiting professor Rice University,professor Universita' di Catania, Universita' di Salerno, Universita' di Roma La Sapienza. Dr. Zirilli is the author of over one hundred scientific publications. His main research interests: quantum field theory, nonlinear analysis, numerical optimization, direct and inverse acoustic and electro-magnetic scattering, processing of remotely sensed data. Member or former member of the following editorial boards: *SIAM Journal of Optimization*, *Journal of Optimization Theory and Applications*, *Journal of Global Optimization*, *Waves in Random Media.*

**ABSTRACT: Inverse scattering and smart obstacles**

Direct and inverse scattering problems involving smart obstacles are proposed and some ideas to study them are suggested. A smart obstacle is an obstacle that when hit by an incoming acoustic wave reacts circulating on its boundary a pressure current, that is a quantity dimensionally given by a pressure divided by a time, in order to generate a scattered wave that pursues a preassigned goal. In our models the smart obstacle pursues one of the following goals: 1) to be undetectable, 2) to appear with a shape and boundary impedance different from its actual ones, 3) to appear in a location different from its actual one eventually with a shape and boundary impedance different from its actual ones. The direct scattering problem for a smart obstacle is modelled as an optimal control problem for the wave equation. In the study of inverse problems we limit ourselves to time harmonic problems and we generalize to smart obstacles some methods used in inverse scattering for (non smart) obstacles.


## Gregory J. Gbur

**Assistant Professor of Physics and Optical Science**
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**Gregory Gbur** received his B.A. in physics from the University of Chicago in 1993, and his M.A. and Ph.D in physics from the University of Rochester in 2001, on the subject of "Nonradiating sources and the inverse source problem." He performed postdoctoral research in Rochester under Professor Emil Wolf from 2001-2002, and then worked under Professor Taco Visser at the Free University of Amsterdam from 2002-2004. He is currently an Assistant Professor of Physics and Optical Science at UNC Charlotte. His research interests include inverse scattering problems, optical coherence theory, and light interactions on the nano-scale.


**Abstract: Nonradiating sources, nonscattering scatterers, and other 'invisible' objects**

The possible existence of 'invisible' objects has significant consequences for a number of inverse problems, in particular the inverse source and scattering problems. In this talk I review the curious history of so-called nonradiating sources and nonscattering scatterers, and discuss some of their interesting properties.


# Qing H. Liu

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**QING H. LIU** received the Ph.D. degree in electrical engineering from the University of Illinois at Urbana-Champaign in 1989. His research interests include waves and their application in subsurface and biomedical sensing and imaging, design optimization of high-speed electronic packaging and nanodevices. He has published more than 300 papers in these areas in refereed journals and conference proceedings. He was a Research Scientist and Program Leader with Schlumberger-Doll Research, Ridgefield, CT from 1990 to 1995. From 1996 to 1999 he was a faculty member with New Mexico State University. Since June 1999 he has been with Duke University where he is now a full Professor. Currently he serves as an Associate Editor for *Radio Science*, an Associate Editor for *IEEE Transactions on Geoscience and Remote Sensing*, for which he also served as a Guest Editor for a special issue on computational methods. He received the 1996 Presidential Early Career Award for Scientists and Engineers (PECASE) from the White House, the 1996 Early Career Research Award from the Environmental Protection Agency, and the 1997 CAREER Award from the National Science Foundation. In 2005 he was elected a Fellow of IEEE for his contributions to computational electromagnetics and subsurface sensing applications.


## ABSTRACT: Inverse Problem for 3D Objects in Layered Media

Sensing and imaging in layered media are indispensable for biomedical and other subsurface diagnostic applications. Given an imaging modality, our goal is to achieve the highest resolution possible with the largest probing volume. Unfortunately, resolution and probing volume are often two competing factors, especially for electromagnetic and acoustic wave modalities where attenuation in general increases with frequency. The critical ingredients for achieving high resolution are the full exploitation of the physics governing the imaging experiment, and accurate and efficient image reconstruction algorithms. In this presentation, a novel nonlinear inverse scattering algorithm based on a new scattering approximation, the diagonal tensor approximation (DTA), will be described for the inverse problem for 3D objects in layered media. Inversion of experimental results confirms that our developed method can achieve the so-called super-resolution as a result of incorporating the full physics in our inverse scattering algorithm. Applications in microwave imaging for breast cancer diagnosis, subsurface sensing of buried targets, and through-the-wall imaging will be demonstrated.


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**Gary S. Brown** was born in Jackson, MS on April 13 1940. He received the B.S., M.S., and Ph.D. degrees all in Electrical Engineering from the University of Illinois, Urbana-Champaign. From 1963-1967, he was a Research assistant in the old Antenna Laboratory of the University of Illinois, Urbana-Champaign, where he was involved with direction finding, shaped beam antennas, and millimeter waveguides. While in the U.S. Army Signal Corps (1967-1969) he served in an engineering capacity dealing with the Integrated Wide-band Communications System (IWCS) in the republic of Vietnam. During 1970, he was employed by TRW Systems Group, Redondo Beach, CA, where his work involved monopulse, ECM, and multiple-beam antenna analysis and development. From 1971-1973, he was with the Research Triangle Institute, NC, where his primary area of interest was spaceborne radar altimetry. From 1973-1985, he was employed by Applied Science Associates, Inc., Apex, NC, where he worked with microwave remote sensing, rough surface scattering, and propagation through random media. In 1985, he joined the faculty of Virginia Polytechnic Institute and State University, Blacksburg, VA where he is presently Director of the ElectroMagnetic Interactions Laboratory (EMIL) and holds the Bradley Distinguished Chair of Electromagnetics. Dr. Brown is a member of Commissions B and F of U.S. National Committee of the International Union of Radio Science (UENS-URSI) and is the immediate past Chair of the organization. He was President of the Antennas and Propagation Society of the Institute of Electrical and Electronic Engineers in 1988 and received the R.W.P. King Award in 1978 and the Schelkunoff Best Paper Award the latter with Jakov Toporkov and Roger Marchand in 1999.


**Abstract: Surface Wave Propagation over a Gently Undulating Rough Surface: a Forward Problem with Inverse Applications**

Electromagnetic surface waves have long been used for broadcast and low frequency communications. However, because these waves propagate along the air-ground interface and penetrate into the ground a limited distance, they may be capable of accomplishing remote sensing of surface and subsurface features. The greatest hindrance to this potential use is the scattering of the surface wave by objects on the surface such as roughness, foliage, etc. It is well known that surface roughness spectral components having wavelengths the order of one-half the electromagnetic wavelength or $\lambda_0/2$ are primarily responsible for scattering in the backscatter direction. However, it is not obvious what happens to a surface wave propagating over a gently undulating surface having no roughness components near to $\lambda_0/2$. The purpose of this work is to obtain an estimate of what happens in this limit. The analysis starts with determining an approximate expression for a surface wave propagating along a gently undulating surface having a one-dimensional local radius of curvature that are large compared to $\lambda_0$. The average wave propagating along the undulating surface is found and the complex propagation constant of this average is determined. Of particular importance here is the slow wave nature of the wave and the interplay of the rms height and the correlation length in the attenuating part of the wavenumber. The differential reflection coefficient is determined approximately for the forward traveling wave on the undulating surface. The reflection coefficient along the continuously varying surface is found to depend directly on the slope of the surface and on the ratio of the free space wavenumber to the wavenumber in the ground. Thus, by monitoring the reflections along the surface, one could potentially monitor the slope of the surface.

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**Marc Saillard** was born in Marseille (France) in 1961. He received the "Agrégation" in Physics in 1985 and a Ph.D thesis from the University of Marseille in 1990, entitled *Theoretical and numerical study of light scattering from dielectric and conducting rough surfaces*. From 1990 to 1997, he was Researcher at CNRS (National Center for Scientific Research), where he started working on electromagnetic probing through a collaboration with BRGM (French mining and geological research agency). Then he became Professor at University of Provence in Marseille (1997-2003) and created the Remote Sensing group of Institut Fresnel, mainly focusing on ocean remote sensing and inverse scattering in random media. He is currently Professor at the University of Toulon (2003-) where he joined the geophysics laboratory (LSEET) to work on pluridisciplinary projects about remote sensing of environment. M. Saillard has published about 50 papers in international Journals, mainly in *InverseProblems*, *Waves In Random Media*, *IEEE Journals* and *J. Opt. Soc. Am. A*. IOP Fellow since 2004, he is currently Associate Editor of *Waves in Random and Complex Media* (Taylor & Francis, formerly WRM).

**Abstract: Surface clutter removal in inverse scattering from buried objects**

The problem of imaging an object buried at very low depth beneath a rough surface is addressed. In a first step, assuming multi-static wide-band data have been recorded from a set of antennas located along a piece of line, detection is performed through correlation $C(\mathbf{X})$ of data sets associated with two transmitters located symmetrically from the surface point $\mathbf{X}$ under test. Averaging over various locations of transmitters and receivers damps the oscillations due to surface scattering and a peak associated with target contribution comes out, as predicted by a low frequency approximation and confirmed by computations based on a rigorous integral formalism. This technique has been numerically tested in various configurations, and the performance of the detector has been estimated against roughness parameters through computation of probability of detection *vs* false alarm rate.

To avoid reconstruction or prior knowledge of the surface profile, an inverse scattering problem based on iterative minimization of a cost function built with $C(\mathbf{X})$ has been solved. In this algorithm, it is assumed that the interface is flat and the remaining fluctuations of $C(\mathbf{X})$ considered as noise. It permits us to use forward solvers taking the interface into account through Green's function and save a lot of computation time, keeping in mind that the goal is mainly to classify the targets, not to provide accurate maps of permittivity.


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**Abstract: Investigation of the Stability of Electromagnetic Time-Reversal Imaging**

Time reversal imaging is based on the idea of measuring wideband scattered fields, phase conjugating them (in frequency), and then propagating them back into the domain computationally using the appropriate background-medium Green's function. The phase conjugation in frequency is equivalent to time reversal, when viewed from the time domain. The challenge of this problem is found in the need for the background Green's function, which may be known imprecisely. In this talk we present experimental results for electro-magnetic time reversal in complex media, examining the sensitivity of the imaging process to the accuracy of the Green's function used. We also examine image sensitivity to system bandwidth and array-aperture size.


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**Anthony Devaney** is a Professor of Electrical and Computer Engineering at Northeastern University in Boston, MA. Professor Devaney received his Ph.D. from the Institute of Optics at the University of Rochester in 1971, an M.S. in Engineering and Applied Science from Yale University in 1966 and a B.S. in Electrical Engineering from Northeastern University in 1964. Professor Devaney is a member of the Acoustical Society of America and the Institute of Electrical and Electronics Engineers and is a Fellow of the Optical Society of America. Professor Devaney has been a member of the Editorial Board of *Ultrasonic Imaging* since 1984 and was Topical Editor of the *Journal of the Optical Society of America* from 1984-1986. He has also been a feature editor for a special issue on *Inverse Problems in Propagation and Scattering, Journal of the Optical Society of America,* and a member of the board of editors for the journals *Wave Motion* (1988-1992), *Inverse Problems*, 1988-1993 and *Electronic Imaging*, 1988-1993. Professor Devaney has seven patents and over one hundred publications and has given more than one hundred papers at scientific workshops and conferences and university and corporate symposia.

## Abstract: Time Reversal Imaging and Inverse Scattering


The classic *time reversal imaging problem* consists of imaging (locating) a set of discrete point scatterers from scattered field data in the form of the *multistatic data matrix* $K_{j,w}(\omega)$ measured at one or more temporal frequencies $\omega$. The multistatic data matrix $K_{j,w}(\omega)$ is defined to be the scattered field amplitude measured over a set of receiver points $\beta_j$, $j = 1,2,\ldots, N_\beta$ for point source illumination at a set of transmitter points $\alpha_k$, k = 1,2,..., $N_\alpha$ and is also the data employed in the classic *inverse scattering problem*. This latter problem does not assume the scatterer being interrogated consists of a set of discrete point scatterers but, rather, has as its goal the quantitative reconstruction of the scatterer properties regardless of its structure. In this talk it is shown that these two apparently different problems have, in fact, a unified formulation that involves the process of time reversal (or field back propagation) as a vital component of their solution. Recent results in both problems will be reviewed and both computer simulated and real data driven examples will be presented.



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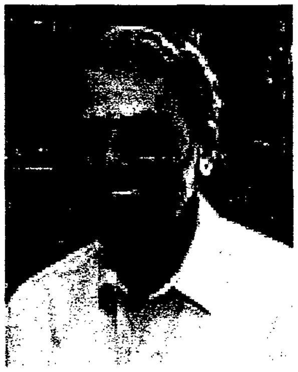

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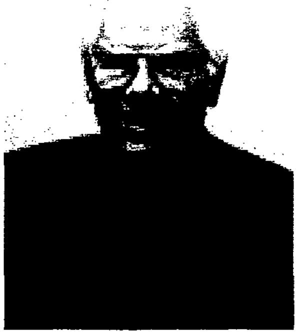
**Abstract: Rough Surface Reconstruction**

The direct problem of modeling the scattering from known periodic or rough surfaces has received much attention and there are several exact theoretical methods to describe the scattering. Many are based on integral equations. These integral equation formalisms can be defined using the kernel of the integral operator, a function to two variables representing the "source" and "receiver" points on the surface. When both are in coordinate space (CC) we have the usual integral equation method. Other methods can be derived which place one or the other variable in spectral space (SC and CS), or both in spectral space (SS). We describe the general theoretical formalism for both acoustic and electromagnetic scattering problems using these different formalisms.

For inversion problems the most useful of these methods is the SC method. We describe two surface reconstruction algorithms using the SC method. Both require some approximation. The first uses perturbation theory on the surface height. The resulting algorithm is independent of boundary unknowns and so does not require any approximation on them. The "data" required for the reconstruction involves the incident and scattered fields. The second uses the Kirchhoff approximation on the boundary unknowns, for example on the normal derivative of the field for a Dirichlet problem. It also uses both incident and scattered field data and an approximate Fourier transform relation.

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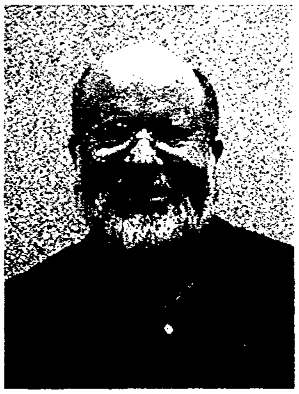
## Abstract: The Design of Surfaces With Specified Scattering Properties

In the usual formulation of the inverse problem in rough surface scattering, scattering data such as the angular and polarization dependence of the intensity of waves scatted from a rough surface are provided by experimentalists, and the goal is to extract the surface profile, or some statistical properties of it, such as the power spectrum of the surface roughness, or just the rms height of the surface, from these data. In contrast, we consider a somewhat different type of inverse problem, namely the design of a random surface that scatters in a specified manner a wave incident on it. Two different cases are discussed: (i) the scattered field is required to have a prescribed angular dependence of its mean intensity; and (ii) it is required to have a specified wavelength dependence of its mean intensity at a fixed scattering angle. Applications of each of these types of surfaces are indicated.

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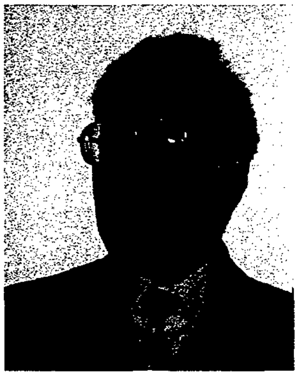
**Thomas Lucas** began his professional career working at Martin-Marietta as a senior engineer doing scientific programming. After completing his doctorial work at Georgia Tech in applied mathematics he joined the faculty of the Dept. of Mathematics at UNC Charlotte. His early research was in the area of spline approximation and the finite element method. During the 80's he worked with researchers at the David Taylor Naval Research Center on the nonlinear problem of finding the free surface generated by a specific naval hull form with forward movement at various speeds. Dr. Lucas invented a new technique that yielded unusually close correspondence to experimental measurements. Since that period he has been working on inverse scattering problems related to optical tomography and the detection of land mines. His more recent work involves significant simplifications from his earlier collaborations, and extends the interior coefficient recovery problem to the frequency domain with multiple sources. He is a great fan of the software package FEMLAB (used with Matlab). He has been supported by grants from David Taylor for ship waves, the NSF for supercomputer time and more recently inverse scattering in the time domain, and the Office of Army Research for land mine detection.


**Abstract: A New Inverse Solver for Diffusion Tomography Using Multiple Sources**

This is a preliminary report on the development of a diffusion based inverse solver for the Helmholtz equation in the frequency domain, in the context of optical tomography. This utilizes a great simplification of the previously developed Elliptical Systems Method with the use of a certain new PDE of the 2nd order, with related boundary and special conditions. In this report we consider the recovery of just the absorption coefficient with both theory and numerical examples, focusing on the case of incomplete data collection using multiple continuous wave (zero frequency) sources. The incomplete data collection is over a rectangular region and includes use of sources and detectors limited to the top and bottom sides, detectors on the transmitted sides only and detectors on the back-reflected sides only.

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**Iosif M. Fuks** was born in June 13, 1940, in Kharkov, Ukraine. He received the MS degree in theoretical physics from the University of Kharkov in 1962 and joined the Institute of Radio Physics and Electronics Ukrainian Academy of Sciences. In 1966, from the Acoustics Institute of Academy of Sciences of the USSR (Moscow), he obtained the Candidate of Science (Ph.D.) degree on the theory of radio waves scattering by statistically rough surfaces. In 1978 he received the Doctor of Science (Physics and Mathematics) degree from the University of Kharkov and became a full Professor of Space Radio Physics at Kharkov University. In 1969 he was rewarded by the Group on AP IEEE with the Certificate of Achievement for Outstanding Contribution for 1968 Transaction Paper entitled *Very High Frequency Radio Wave Scattering by a Disturbed Sea Surface.* In 1987 he obtained the Ukrainian National Science and Technology Prize for his foremost results on theory of radio wave scattering, propagation, and diffraction. In 1980, he joined the Institute of Radio Astronomy of the Ukrainian National Academy of Sciences in Kharkov, where he has been a head of the Space Radio Physics Laboratory since 1985. Since 1997 he has been working for NOAA Environmental Technology Laboratories at Boulder, Colorado. He has co-authored more than 150 papers, covering different aspects of waves propagation and diffraction theory, among them one of the first world-known books on theory of *Wave Scattering from Statistically Rough Surfaces* ( Pergamon Press, 1979). Professor Fuks's research interests lie in the statistical theory of diffraction on rough surfaces and wave propagation through random media, thermal electromagnetic emission from natural objects, analytical and numerical simulation methods for solving diffraction, and radio wave propagation problems.


## ABSTRACT: Statistical Properties of the Ensemble of Specular Points at a Randomly Rough Surface

When a random rough surface is illuminated by light or high-frequency radio waves, the specular reflected points make an ensemble the statistical properties of which are of a great interest not only for a general theory of scattering, but also for many practical applications, ranging from real-time monitoring of man-made surface roughness, to sea roughness parameter measurements using sunlight flares at the surface. Apparently, Longuet-Higgins was the first to employ the theory of random functions for solving this problem. In particular, the explicit equations for the spatial density of extremums and saddle points were derived for Gaussian surfaces, and the fundamental relations between them were established. In this presentation, the statistical parameters are obtained for the ensemble of specular points at randomly rough Gaussian statistically isotropic surface at normal incidence. The joint probability distribution functions (PDFs) of specular point heights and total curvatures are derived for maximums, minimums, and saddle points separately. The joint PDF of brightness and surface elevations of specular points, as well as the height PDF of specular points which brightness exceeds the given threshold are obtained analytically in the explicit form. The data of computer simulation for a specific case of roughness with Gaussian correlation function agrees with the analytical results.


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## ABSTRACT: Inverse Scattering Using Evolutionary Strategies

The scattering of electromagnetic waves, produced by their incidence on a rough surface, has been widely studied in the past. The inverse scattering problem, on the other hand, that consists of the reconstruction of the profile of a surface from scattering data is more complex and has been less studied. In this paper, we present a study of inverse scattering from rough surfaces. The goal is to retrieve the unknown surface profile function from scattered intensity data, treating the problem as an optimization problem. The angle-resolved scattered intensity used as input data for the algorithms depends on the surface profile function in a complicated way but, for one-dimensional surfaces, the direct problem can be solved numerically. The closeness of a proposed profile to the original one can be estimated through the difference between the measured angular distribution of intensity and the angular distribution of intensity obtained by solving the direct scattering problem with a trial profile. The goal then would be to find a surface for which the measured intensity and that generated by the trial surface are equal. When this happens, and if the solution to the problem is unique, the original profile has been retrieved. The inverse scattering problem is then reduced to the problem of minimizing a cost function.

Results for inversion procedures, combining evolutionary strategies (H. P. Schwefel, *Evolution and Optimum Seeking*, Wiley, NY, 1995) and the downhill simplex method (J. Nelder and R. Meade, *Computer Journal*, 7, 308, 1965) will be presented. The evolutionary strategies employed are the elitist ($\mu/\rho+\lambda$) and the non-elitist ($\mu/\rho,\lambda$) strategies with recombination. Here $\mu$ is the number of parents in the initial population, $\lambda$ is the number of offspring generated by means of the genetic operators, and $\rho$ is the number of members of the population that generate an intermediate population through recombination. Once the evolution strategies have reached the termination criterion, the downhill simplex algorithm is employed to improve the solution.

Our results show that surface profiles can be reconstructed from far-field intensity data even in the presence of noise and multiple scattering. Some issues concerning the uniqueness of the solution appear in the results and will also be discussed. The procedure employing the non-elitist strategy with recombination $\rho = 2$, appears to be more stable than the other algorithms studied.

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**ABSTRACT: Minimum-phase-based Inverse Scattering Algorithm**

Laboratory controlled data were recently provided by the Institut Fresnel to assist with the development and validation of inverse scattering algorithms [1]. The method we have been using for some years to invert scattered field data from strongly scattering objects is based on a nonlinear filtering procedure [2]. Successful filtering of this type requires that the data being processed represent a minimum phase function. The properties of minimum phase functions are well understood in 1D problems and the condition can be enforced using an appropriate reference wave. In 2D or higher dimensional problems, we describe the conditions for minimum phase and show how a reference wave can be numerically combined with measured complex scattering data in order to enforce this condition. We present results using the data provided and comment on the practical implementation of this method.

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**Abstract: Inverse Scattering and Nano-Optics**

Nano-optics, also known as near-field optics, refers to the study of optical phenomena on sub-wavelength scales. In this size range, there are exciting prospects for the development of novel devices and materials. There are also opportunities to develop novel forms of optical imaging. This talk will describe several inverse scattering problems that arise naturally in this setting. The challenge is to overcome the effects of diffraction which limits resolution to the scale of the wavelength of light. The mathematical approach to this problem is based on inverse scattering theory (IST) for electromagnetic wave fields with evanescent components. In joint work with Scott Carney, it has been shown that this formulation of IST has a markedly different mathematical structure than conventional IST for propagating waves. In particular, the inverse scattering problem with evanescent waves is weakly nonlinear owing to the the exponential decay of these waves in nano-scale systems. This problem has been analyzed and inversion formulas developed for the inverse scattering problems which arise in scanning probe microscopies such as photon scanning tunneling microscopy, total internal reflection microscopy, and near-field scanning optical microscopy. Theoretical studies, numerical simulations and experiments will be described.


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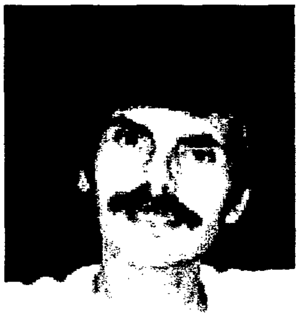


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JOHN SYLVESTER received his Ph.D. from the Courant Institute and has been a Professor in the mathematics department at the University of Washington since 1988. He primarily studies differential equations with applications to scattering, inverse scattering, and remote sensing. Some recent publications are: Steven Kusiak and John Sylvester, *The scattering support*, *Comm. Pure Appl. Math.*, 56(11): 1525 - 1548, 2003; John Sylvester and James Kelly, *A scattering support for broadband sparse far field measurements*, *Inverse Problems*, 21(2):759 - 771, 2005.


**ABSTRACT: The Scattering Support of a Far Field**

In the inverse source problem, we seek to infer properties of a source based on remote observations of the monochromatic field it radiates. Our mathematical model is the Helmholtz equation at a fixed wavenumber. The problem is linear, but complicated by non-uniqueness, i.e. the existence of non-radiating sources. These sources produce no far field; they are the kernel of the linear map from sources to observations. Because any open set supports a non-radiating source, there are arbitrarily large (supported on big sets) sources that radiate any monochromatic far field.

We discuss how to find a unique smallest set which radiates any given far field. We will give explicit examples to illustrate that even this is not possible in general, but that it is possible to associate with every far field the smallest convex set, and even the smallest union of well-separated convex sets, that radiates that source. We will also describe an algorithm that uses the *rapid transition to evanescence* of the decomposition of the field into spherical harmonics to compute the smallest convex set.


## Markus Testorf

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**Markus E. Testorf** received his M.S. in physics and his Ph.D. in physics/applied optics both from the University of Erlangen in Germany. He worked as a postdoctoral research fellow at the National Institute of Astrophysics, Optics, and Electronics in Puebla, Mexico, at the Institute of Optical Communication Engineering, University of Hagen, Germany, at the Thayer School of Engineering at Dartmouth College, and at the University of Massachusetts-Lowell. At Umass he went on to serve as research director for the Center of Electromagnetic Materials and Optical Systems and became an assistant professor in the Department of Electrical and Computer Engineering before returning to Thayer School. He is a member of the Optical Society of America (OSA), the American Institute of Physics, the International Society for Optical Engineering (SPIE), the European Optical Society, and the German Optical Society (DGaO). He is a frequent reviewer for a number of technical journals. He is a topical editor for *Applied Optics*, and has served as a program committee member on various occasions. Markus Testorf has written or co-authored over 100 technical articles, of which about 40 have appeared in peer-reviewed journals.


**Abstract: Retrieval of Phase Information in Phase-Space**

Phase-space representations and joint-time frequency transforms are known to be valuable tools for solving specific phase-retrieval problems. This includes phase-space tomography of optical signals, as well as frequency-resolved optical gating(FROG) for characterizing short time optical pulses by measuring the spectrogram of the pulse. Recent studies have identified additional applications of phase-space methods to deterministic phase retrieval schemes.

The presentation will promote the phase-space analysis of phase-retrieval methods as a fundamental paradigm. Based on the phase-space analysis of various phase retrieval schemes it is shown that the inherent redundancy of the Wigner distribution function and its Fourier transform, the ambiguity function, provide significant flexibility for developing phase recovery methods for accommodating different experimental constraints. In particular, each phase-retrieval scheme can be characterized by the fraction of the ambiguity function which is experimentally accessible. Then, phase-retrieval is defined as recovering the entire ambiguity function or Wigner function from a finite and incomplete set of samples.

It is also shown that iterative phase-retrieval methods can be reinterpreted in phase-space as well. This provides insight into the application of iterative phase-retrieval to optical systems other than a Fourier transform system. In addition, it is possible to construct hybrid phase-retrieval schemes, which combine the advantages of deterministic phase retrieval and iterative phase-retrieval techniques.


# Michael V. Klibanov

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**Michael V. Klibanov** received his MS degree in Mathematics from Novosibirsk State University in Novosibirsk, Russia in 1972. In 1977 he got his PhD in Mathematics from Ural's State University (Ekaterinburg, Russia). His third degree of Doctor of Science in Mathematics was received in 1986 from Computing Center of Siberian Branch of The Russian Academy of Science (Novosibirsk). He is with The Department of Mathematics of The University of North Carolina at Charlotte since 1990 (professor since 1993). His research interests are in Inverse Problems for Partial Differential Equations, including inverse problems in optics. He has published more than one hundred research papers and one book.


## Abstract: Some Inverse Problems including the Phase Problem in Optics

The talk will consists of two parts. In the first part global uniqueness theorems and Lipschitz stability estimates will be presented for some coefficient inverse problems for hyperbolic equations. In particular the case of an infinite domain (octant) will be considered and a conclusion about the refocusing of a time reversed wave field will be drawn. In the second part a uniqueness theorem of the problem of the recovery of a 2-D function from the absolute value of its Fourier transform will be presented. This is the so-called phase problem in optics.


# Irena Lasiecka

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IRENA LASIECKA received her M.S. (1972) and her Ph.D. (1975), both in Applied Mathematics, from the University of Warsaw, Poland. From 1975-1980 she was Assistant Professor at the Control Theory Institute at Polish Academy of Sciences in Warsaw. She then moved to the University of California at Los Angeles, Systems Science Department, where she was a postdoctoral fellow from 1977 – 1979 and Visiting Assistant Professor from 1979 – 1980. In 1980 she became Assistant Professor at University of Florida, Gainesville, Mathematics Department, followed by positions as Associate Professor (1981-1984) and then Professor (1984-1987) at Gainesville. In 1987 she moved to the University of Virginia in Charlottesville, Department of Applied Mathematics, where she was Professor until 1998, when she began her current position as Professor in the Department of Mathematics. Dr. Lasiecka has held visiting appointments at numerous universities around the world, including Liege University, Belgium; Scuola Normale Superiore, University of Bologna, University of Trento, and Instituto di Calcolo Scientifico in Italy; Int. Institute for Applied Systems Analysis in Laxenburg, Austria; Mittag Leffler Institute in Stockholm; and the Institute for Mathematics and Applications at the University of Minnesota, USA. Her research interests are in Applied Mathematics, Partial Differential Equations and related control theory.


**ABSTRACT: Wellposedness and uniform decay estimates for nonlinear Schrodinger equation with boundary damping**

We consider semilinear Schrodinger equation with a boundary dissipation. No restrictions on the growth of the damping are imposed. The main results presented are the following:

• Wellposedness of finite energy ($L_2(\Omega)$) solutions.
• Uniform decay rates for the $L_2(\Omega)$ energy without quantifying behavior of the damping at the origin.

The result presented solves an open problem of uniform stabilization of $L_2(\Omega)$ energy under the influence of boundary dissipation. The key technical tools used for the proof are "inverse" stability estimates developed for Schrodinger evolutions with boundary terms in negative Sobolev spaces.

# D. Michael Milder

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**D. Michael Milder** is a co-founder of Arete' Associates in Sherman Oaks, CA. Born and raised in Los Angeles, he was educated at Caltech (BS, Physics) and Harvard (PhD, Physics; thesis, Rotating Stellar Systems). He is a committed nonspecialist, working and publishing in underwater acoustics, surface-wave and internal-wave dynamics, decision theory, and rough-surface scattering of sound and radio waves. His hobbies are ethnic folk music, photography, and soccer refereeing.

**Abstract: "The Virtual Periscope"**
**Paul W. Carter and D. Michael Milder**

To detect surface ships a submarine must rise close to the surface and expose a periscope. This sacrifices stealth, limits speed, and raises the risk of collision. By combining an understanding of ocean surface dynamics with modern computational power, deep submarines can at last be given the ability to see the world above the surface – without exposing a mast. The submarine commander could visually target and classify ships, check the area clear of collision threats before ascending, conduct a visual attack at depth and speed, and extend its safe operating region well into the littoral.

The Virtual Periscope is an optical sensor and signal processing algorithm under development for the detection and classification of surface ships from a fully submerged platform. Unlike a conventional periscope, which collects light from a position above the ocean surface, the VP collects skylight penetrating through the ocean surface with one or more upward-looking cameras positioned below the surface.

According to Snell's Law, all the light above the surface is refracted below the surface into a cone of light that can be imaged by an upward-looking underwater camera equipped with a wide angle lens. However, the imagery collected by such a camera is unintelligible due to the distorting influence of waves on the ocean surface. Due to this distortion, a human observer looking at the surface from below is incapable of detecting ships on the horizon until they subtend an angle of about 20 degrees or more. A system that relied on this method of detection would be tactically useless. Therefore, sophisticated signal processing techniques are required to extract useful information from the distorted imagery, especially for the portion of the scene of greatest interest near the horizon.

The VP hardware consists of one or more upward-looking cameras viewing the underside of the ocean surface. The camera field of view must be about 130 degrees to encompass the entire cone of refracted light and reconstruct the entire hemisphere above the surface. A camera at a typical depth of 20 m with a CCD having 1024 pixels on a side would have an 8 cm pixel size projected on the mean surface. Images are collected at a rate of approximately 8 Hz and are analyzed by the VP algorithm. The algorithm applies multiple signal processing methods to the images and presents processed above-surface imagery and target detection information to the operator.


## Paul Carter

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**Paul Carter** received his M.S. and Ph.D. in Physics from CalTech in 1996 and 1999, and his B.A. in Physics/Mathematics from Rice University in 1993. Since joining Areté in 1999, Dr. Carter has been involved in a variety of programs related to submarine communication and sensor systems. He has enhanced a model describing the flushing of towed arrays from stowage tubes, evaluated atmospheric noise reduction techniques for ELF communications, and supported the development of the Virtual Periscope, an optical sensor system providing through-surface viewing of targets above the ocean. Prior to joining Areté, Dr. Carter was a member of two experimental collaborations studying the quark-gluon substructure of protons. As part of this work, he wrote software for the reconstruction of particle collisions, participated in the construction and calibration of several components of a particle spectrometer, measured the spin-azimuthal dependence of the cross section of pion electroproduction, and was instrumental in the design, construction, and optical characterization of the world's first aerogel-based ring-imaging Čerenkov detector of high-energy charged particles.

**Abstract: "The Virtual Periscope"**
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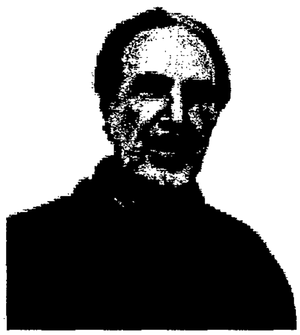

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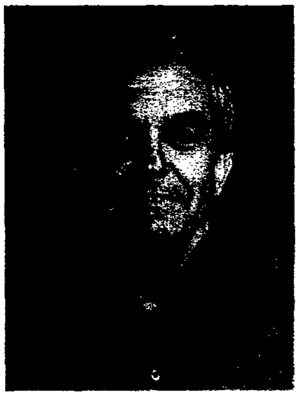
His research interests are: mixed problems for single parabolic, hyperbolic and Petrowski type (e.g., plate-like, Schrödinger) partial differential equations (PDE's), as well as for systems of coupled PDE's (thermo-elastic equations, noise reduction models, shell equations); related optimization and control theory, including differential and algebraic Riccati operator equations for infinite-dimensional quadratic cost optimal control problems with unbounded operators; related differential game problems; optimal (sharp) regularity theory (interior regularity and boundary trace regularity) of wave, plate-like equations, Schrödinger equations, PDE systems, etc.; energy methods, functional analytic techniques, pseudodifferential and micro local analysis techniques; Riemann geometric methods; exact controllability and uniform stabilization of conservative problems (e.g., wave and plate equations); boundary stabilization of parabolic equations including Navier-Stokes equations; abstract differential equations in Banach space with unbounded operators, such as they arise as models of mixed PDE problems; operator theory; semigroup theory; retarded (functional) differential equations.

ABSTRACT: **Pointwise Carleman Estimates for Schrodinger Equations: Global Uniqueness, Observability and Stabilization**

We shall present pointwise Carleman type inequalities for general Schrodinger equations defined on a multi-dimensional bounded Euclidean domain. At first, we consider the case of the Euclidean Laplacian perturbed by energy level (H1-) terms vith variable non-smooth coefficients (in time and space). Next, the Euclidean Laplacian is replaced by a variable coefficient (in space) elliptic operator or, more generally, by the Laplacian on a n dimensional Riemannian manifold. Implications include inverse type a-priori estimates of interest in control theory (such as continuos observability and uniform stabilization inequalities) as well as global uniqueness results.

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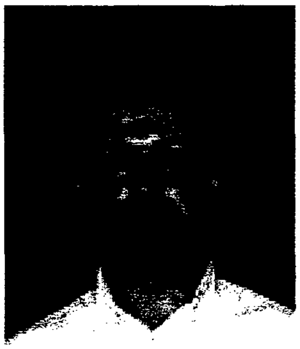
VALENTIN FREILIKHER graduated from Kharkov State University in 1965, and then joined the Institute of Radiophysics and Electronics Ukrainian Academy of Science, where he worked until 1991. He received his Ph. D. in Theoretical Physics in 1970. In 1988 headed the Radiophysical Division in round-the-world expedition on Scientific Research Vessel "Academik A. Vinogradov". In 1991 he immigrated to Israel where he accepted a Professor position at the Department of Physics Bar-Ilan University and set up and took charge of the Microwave Remote Sensing Center. Dr. Freilikher's main field of research is the physics of wave processes in random media. He has published about 200 papers. His hobbies are skiing, hiking, kayaking, rafting.

**ABSTRACT: Inverse scattering problem for one-dimensional random systems**


In the talk, the results of the theoretical, numerical, and experimental studies of localized states in one-dimensional open disordered systems are presented. It is shown that the localization of energy and anomalously high transmission associated with the localized modes are due to the existence inside the sample of transparent (for a given resonant frequency) segments with the minimal size of order of the localization length. A mapping of the stochastic scattering problem in hand onto a deterministic quantum problem is developed. It is shown that there is no one-to-one correspondence between the localization and high transparency: only small part of localized modes provides the transmission coefficient close to one. The maximum transmission is provided by the modes that are localized in the center, while the highest energy concentration takes place in cavities shifted towards the input. An algorithm is proposed to estimate the locations and pumping rates of effective resonant cavities inside a disordered sample by the external measurements of the field reflected by the sample. Weak losses in the sample affect drastically the conditions of excitation and observation of resonances, and improve their detectability.

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YURI GODIN received the M.S. degree from the St. Petersburg Polytechnic University, Russia, in 1985 and the Ph.D. degree in applied mathematics from the Technion, Israel, in 1994. His research interests include composite materials, photonic crystals, numerical analysis, and mathematical modeling.


ABSTRACT: **Propagation of waves in a one-dimensional random binary medium**

We calculate exactly the Lyapunov exponent which provides a measure of the spatial decay of the wave amplitude, and the integrated density of states for a random one-dimensional waveguide whose parameters (for example, density and elastic compliance for the elastic waveguide) are functions of a binary Markov chain. For all values of interest short and long wave asymptotic expansions are obtained. Finally we discuss conditions of propagation and localization of waves in a binary random medium.


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## Abstract: Inverse Problems for Diffraction Gratings


We consider the inverse diffraction problem to recover a two-dimensional periodic structure from scattered waves measured above and below the structure, which is of great practical importance in modern diffractive optics, e.g., in quality control and design of diffractive elements with prescribed far field patterns. The talk concentrates on the profile reconstruction problem where the interface between two homogeneous materials is determined.

The first part of the talk is devoted to new uniqueness results for the inverse periodic Dirichlet, Neumann and transmission problems. We present uniqueness theorems for scattering data with finitely many wave numbers generalizing those of [3] and [4]. The second part concerns a profile reconstruction method, which is a periodic version of the Kirsch-Kress method [2] that avoids the solution of direct problems. In this method, the inverse problem is decomposed into the severely ill-posed linear problem of reconstructing the scattered wave from a knowledge of its far field pattern, and into the well-posed nonlinear problem of determining the unknown profile curve. The discretization of the resulting optimization problem then leads to a nonlinear least squares problem. We present numerical examples and theoretical convergence results, which even hold for general Lipschitz profile curves [1].



1. G. Bruckner, J. Elschner, *The numerical solution of an inverse periodic transmission problem, Math. Meth. Appl. Sci.* (2005) 757-778.
2. D. Colton, R. Kress, *Inverse Acoustic and Electromagnetic Scattering Theory*, 2nd Edition, Springer, Berlin, 1998.
3. J. Elschner, G. Schmidt, M. Yamamoto, *An inverse problem in periodic diffractive optics: Global uniqueness with a single wave number, Inverse Problems* (2003) 779-787.
4. F. Hettlich, A. Kirsch, Schiffer's theorem in inverse scattering for periodic structures, *Inverse Problems* (1997) 351–361.


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**George Hsiao** was born in Shanghai, China. He is an engineering graduate of the National Taiwan University. He received his master's degree in civil engineering from Carnegie Institute of Technology and his doctorate in Mathematics from Carnegie-Mellon University. In 1969, Dr. Hsiao joined the Department of Mathematical Sciences at the University of Delaware, where he has been a full professor since 1977. Presently he holds the Carl J. Rees Chair Professor in Mathematics at the University. Dr. Hsiao's education in dual disciplines has influenced his research interests, which include integral equations, partial differential equations, singular perturbation theory, elasticity and fluid dynamics, wavelets, direct and inverse problems in acoustic and electromagnetic scattering. He is one of the leading experts and authorities on variational and boundary element methods for integral equations. The author of more than 150 papers on mathematics, applied mechanics, oceanic environment, rheology and biomedical engineering, Dr. Hsiao has given invited lectures all over the world. He is the co-author of *Maple Projects for Differential Equations*; *Water Waves and Ship Hydrodynamics:An Introduction;* and *Boundary-field Equation Methods for a Class of Nonlinear Problems.* Dr. Hsiao was an Alexander von Humboldt-Stiftung senior Fellow and has been award three time research Humboldt fellowships in Germany. Recognized for his excellence as an educator, Dr. Hsiao was the recipient of the Frances Alison Medal of the University of Delaware, the highest faculty award at the University, in recognition of scholarship, professional achievement and dedication.


**Abstract: On an Inverse Scattering Problem for Periodic Structures**

The scattering theory in periodic structures has many applications in microoptics, where periodic structures are often called diffraction gratings. The treatment of inverse problem, recovering the periodic structure or the shape of the grating profile from the scattered field, is useful in quality control and design of diffractive elements with prescribed far field patterns. In this lecture we consider an inverse diffraction grating problem to recover a twodimensional periodic structure from scattered waves measured from above and below the structure. From measured Rayleigh coefficients for several incidence directions, we wish to reconstruct the grating. The problem is reformulated as an optimization problem including regularization terms. The solution is obtained as the minimizer of the optimization problem, where the objective function consists of three terms: the first is the residual of the Helmholtz equation, the second the deviation of the computed Rayleigh coefficients from the measured data, and the third is a regularization term to cope with the ill-posedness of the inverse problem. The solvability and the dependence on the parameter of regularization is analyzed. Some numerical experiments are included based on the finite element discretization for the Helmholtz equation as well as for the corresponding optimization problem in order to demonstrate the practicability of our inversion algorithm.

This lecture is based on a joint work with J. Elschner and A. Rathsfeld of WISE (Weierstrass-Institut für Angewandt Analysis und Stochastik, Berlin, Germany).


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**Andrew Hesford** was born Arlington Heights, Illinois on February 22, 1982. He received his B.S. degree from Washington University in St. Louis in 2002, and his M.S. degree from the University of Illinois at Urbana-Champaign in 2004. Both degrees were in electrical engineering. He is currently pursuing his Ph.D., in the same field, at the University of Illinois. Since 2002, Mr. Hesford has been a research assistant for Professor Weng Chew in the Center for Computational Electromagnetics and Electromagnetics Laboratory. His current research interests include efforts to analyze and reduce the computational complexity of inverse scattering algorithms.

### ABSTRACT: Reducing the Asymptotic Complexity of the Distorted-Born Iterative Method


The distorted Born iterative method (DBIM) relies on the concept of iterative improvement to reconstruct an object's inhomogeneous profile from scattering data. To produce an improvement to an assumed profile requires knowledge of Green's functions and scattered fields from inhomogeneous materials. Such information is obtained numerically using a forward solver. With the Green's functions and scattered fields computed, DBIM relies on the construction and inversion of a Frechet derivative matrix to find the profile correction. This procedure, coupled with the forward solver, accounts for most of the computational demand of DBIM. A clever formulation eliminates the need to construct and store the Frechet derivative, reducing the complexity of DBIM. However, the forward solver still remains a bottleneck. This talk investigates the application of the conjugate gradient-fast Fourier transform method (CG-FFT) and multilevel fast multipole algorithm (MLFMA) to reduce the computational complexity of DBIM. By leveraging specifics of these methods, it is possible to reduce the dependence on both the size of the scatterer and the number of receivers used to collect measurements.

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